



Anagnostopoulos, C., Sextos, A., Bikas, D., Stylianidis, K., Angelides, D., Avramidis, I., & Kyrkopoulou, K. (2017). Alternative Solutions to Preserve the Revealed Byzantine Antiquities at the Venizelou Metro Station of Thessaloniki. *International Journal of Architectural Heritage*, 11(4), 539-553. <https://doi.org/10.1080/15583058.2016.1266415>

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# Alternative solutions to preserve the revealed Byzantine antiquities at the Venizelou Metro Station of Thessaloniki

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**Abstract:** This paper presents the methodological approach adopted to prioritize and comparatively assess alternative design solutions aimed to retain the Byzantine antiquities that were found during the construction works of the new city Metro main line, without cancelling the construction and operation at the Venizelou station in which they were found during excavation. It is shown, on the basis of cost over the respective benefit, that such a challenging engineering task is indeed feasible from both a technical and a financial viewpoint through a pragmatic compromise between the infrastructure logistics and the priceless nature of the archaeological findings. The particular feasibility study was the first of its kind made at a city and national level, it is deemed as a significant contribution to the public debate between the local and governmental authorities that essentially paved the way towards complex engineering solutions, innovative ideas and fruitful interactions, which are currently at the heart of the public debate. Even though it is not seen by any means as the unique solution to the particular problem, it is considered as a useful contribution to the present state-of-the art of potential strategies that can be adopted by decision-makers in resolving a multiple-objective, dual engineering and archaeological problem.

## INTRODUCTION

During the period of economic and cultural globalization, the enhancement of cultural heritage and place identity constitute competitive edges of postmodern European cities in the process of intercity competition – and especially in the field of urban development. Nevertheless, there are still cases pointing dilemmas in cultural heritage management and particular conflicts regarding the construction of major transport infrastructure projects in the vicinity of archaeological sites that associate with the finding or display of ruins. This paper focuses on the recent case of Thessaloniki and the challenge to address two different major aims, namely to accomplish the construction of

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the Venizelou Metro station on the city's main underground line and to preserve the remnants of two major Byzantine roads (*Cardo maximus* and *Decumanus maximus*) excavated by archaeologists during the metro construction in the aforementioned station.

The new Thessaloniki Metropolitan Railway infrastructure is a challenging engineering project of 1.1 billion € initial investment (Figure 1), in a complex engineering environment of soft soil formations, proximity to the sea and exposure to a considerable level of seismic hazard. Above all, the construction of the main Metro line is faced with the challenge to accommodate the fact that the city has been historically built over successive layers, each one corresponding to a different era: Hellenistic, Roman, Byzantine, Ottoman and Modern Greek. Recently, significant archaeological findings were revealed at the Venizelou Metro station (Figure 2) involving the 75m long and 5.5m wide, Roman *Decumanus Maximus* road, also called Byzantine *Middle Road* (“Μέση Ὁδός”) of Thessaloniki, built by the Roman emperor Galerius in the 4th Century A.D. and reconstructed two centuries later (Figure 3). Next to the *Middle Road*, a four pillars gate (“Τετραπύλον”) was also discovered, highlighting the most important crossroad of the city at the time, with the pathway named *Cardo* (Figure 4). This spot essentially marked the commercial heart of the Roman and later, the Byzantine city right below the contemporary city center. Notably, the same crossroad is still considered as one of the most important spots of the modern business center. Facing the extent and cultural significance of the archaeological findings, the question was raised on whether the construction of the Venizelou Metro station was indeed feasible without some kind of intervention and/or transfer of the archaeological remains. The necessity of keeping the construction within the geometrical limits of the initial design and the (already constructed) perimeter diaphragm walls, posed an additional constraint to the engineering problem on top of the tight budget and time constraints. As anticipated, the complexity and significance of the engineering problem triggered an extensive administrative and public debate in an effort to investigate alternative solutions. In this framework, Aristotle University of Thessaloniki formed three working groups by the Departments of Civil Engineering, Architecture, and History and Archaeology, for comparatively assessing different ideas and potential solution paths on the basis of feasibility and cost-benefit. The scope of this paper is to describe the challenging engineering problem and provide an overview of the methodology adopted towards a multi-criteria decision making.

## METRO CONSTRUCTION IN ARCHAEOLOGICALLY SENSITIVE AREAS

Subway construction is commonly bringing into light discoveries of important archeological sites and artifacts, thus posing the challenges to manage rather conflicting objectives; retain construction time and budget at a reasonable level, prevent accidental destruction of valuable information and objects, while at the same time document and store or demonstrate, on site or in a museum, wherever possible, the precious findings. Numerous are the examples of similar archeological challenges within the urban grid that can be classified in three main categories depending on the extent and nature of the findings presented in detail in (Rohde 2016):

- Artifacts: more than 30,000 artifacts were found in Athens, between 1998-2002, spread on 70,000 square meters (Pitt 2012, Stavrakakis 2012), most of which are now exposed within the Metro station in Syntagma (constitution) square. Similarly numerous items were found in Naples, currently exhibited in Duomo and Municipio stations (D'Agostino and Tocco 2013), Rome, Istanbul and Vienna,
- Wrecks and ships: including a 2000 year-old wreck of a Roman freight ship and the remains of Roman wharfs discovered during the construction of the North-South light-rail tunnel in Cologne, Germany, a shipwreck discovered at Yenikapi, Istanbul from the times of the Byzantine times to be exposed in the station (Ozdoğan 2013), and several canoe-shaped boats dating back to 2800-2500 BC that were excavated ten meters below the banks of the Seine river, in Paris now housed in the Carnavalet museum (Marshall and Emblidge 2006),
- Paleolithic fossils: such as the (non-exposed) mammoth bones and teeth that were brought into light in Los Angeles during subway construction between Wilshire/Vermont and North Hollywood stations and the palaeontological findings of Carpetana station in Madrid,
- Buildings and large scale structures: including an entire Aztec pyramid, an entire Aztec neighbourhood and a colonial-era Spanish hospital dating back to the 16th century found between the Mexico City lines 1-2 and 8, respectively,
- Fortress and city walls: such as the case of Sofia, where ruins of the old fortress and city wall were discovered during the planning stage for the lines 1 and 2 at Serdika, thus leading the authorities to build the intersection beneath the archeological reserve, utilize the construction for excavation and set up a pedestrian underpass with an archaeological exposition. Equally interesting was the 15m-long stone wall, most probably a unique remnant of the original battery built in the late Colonial period of 17th century in New York, discovered during construction of a replacement for South Ferry station.

- Pathways and roads: including the impressive "Pompeii of the north", an extensive Roman complex dating back to AD 47 that was discovered right in the heart of London City in 2013 and, as already mentioned, the Byzantine pathways and market remains at the Venizelou station in Thessaloniki.

In many cases, the remarkable findings delayed subway construction and caused disputes over urban and social priorities (Fouseki and Sandes 2009, Vogiatzis 2012), particularly in countries with strict preservation laws such as Italy and Greece among others. It is interesting to observe, however, that even though all findings are in all aspects unique, the technological challenges, the cultural principles and the breadth of potential solutions present numerous similarities.

## THE CASE OF THESSALONIKI: HISTORICAL BACKGROUND

The construction of the Thessaloniki Metro Main line started in June 2006. The idea of an underground railway for Thessaloniki was primarily suggested by the French architect and archaeologist Ernest Hébrard, in the context of the urban redesign of the city in the early 1920s following the Great Fire of 1917 (Gerolymou, 1995). The first phase of the project consists of a 9.6 km underground line with two independent single track tunnels, 13 stations and a depot at the southeast end of the line (Figure 1). The total budget for the project is about 1.1 billion euro, as of 2012. Part of the budget (250M€) is funded from the 3rd EU Common Strategic Framework while another €250 million has been provided as a loan by the European Investment Bank.



Figure 1: Layout of the Thessaloniki Metro. Source: Attiko Metro





Figure 2: Overview of the antiquities found at Venizelou Station. Source: Author's archive; publication under permission by the Attiko Metro



Figure 3: The *Decumanus Maximus* road. Source: Author's archive; publication under permission by the Attiko Metro



Figure 4: Crossroad of *Decumanus Maximus* and *Cardo*. Source: Author's archive; publication under permission by the Attiko Metro

Thessaloniki's metro shares many similarities with the Copenhagen Metro as it features 18 AnsaldoBreda Driverless Metro trains that will run in separate tunnels in each direction. Most of the line (7.7 km) has been constructed by means of two Tunnel Boring Machines, while the remaining section of the line is constructed with the Cut and Cover method.

The construction of the Metro Main line presented an exceptional opportunity for archaeologists to explore under the densely populated city and expose the heart of Thessaloniki's urban life built over different layers during successive eras. The wealth of archaeological findings at the Agia Sofia Station (excavated first) and the Venizelou station that followed, revealed a core sample of the cosmopolitan center of Thessaloniki and brought to light a unique assemblage of the city's walled area ("intra muros"). These findings illustrate vividly the urban development of the city and constitute an exceptional case of seamless and cohesive stratigraphy of different layers that portray the successive historical phases of Thessaloniki from the Hellenistic period since the Modern Greek era. One of the most substantial features that characterize the urban evolution of the city is its continuous history, uninterrupted by important material destructions; this phenomenon of continuity is also observed in other cities of the Hellenistic eastern Mediterranean such as Nicaea, Sinope and Trebizond among others (Bakirtzis, 2003).

As already mentioned, the archaeological scenery at the specific location depicts the commercial heart of the ancient city right below the commercial heart of the modern one, marked by a significant crossroad which involves the 75M long and 5.5m wide, Roman *Decumanus Maximus* road, also called Byzantine *Middle road* (*Μέση Οδός*) of Thessaloniki and it is located underneath the contemporary roadway of Egnatia Street (Association of Greek Archeologists 2013). Notably, such findings were in fact anticipated to be revealed in the particular spot at the Venizelou Station construction area, given the historical data available (9th Ephorate of Byzantine Antiquities memorandum, No: 6128, 18/11/2004).



The designation of the Latin term *Decumanus* indicated the great streets of Roman cities with an eastern direction to the west and they were usually decorated by large squares at the initial part of the roads or the endpoints. The city's main paved road was built on a pathway by the Roman Emperor Galerius during the 4th century A.D. along with the extensive palace complex in the eastern part of the city. Thessaloniki was designed according to the so-called Hippodamian system applied to other large cities of the East (that can be seen from the surviving ruins of the Roman period).

This plan is based on a grid of horizontal and vertical streets that bisect each other in order to form city blocks of approximately 102x58.5 meters size as it also survives to date. Thessaloniki was separated into the lower, coastal city and the upper city, the dividing line being the contemporary Agiou Demetriou Street (*Decumanus Road*).



Figure 5: Overlay of contemporary Venizelou Metro Station with the Late Byzantine Decumanus Maximus road (background photo by Google Earth).

During the late Byzantine period, the road was narrowed as large buildings were constructed along its length (Bakirtzis 2003). Later in the 19th and 20th centuries it was destroyed to a great extent. The *Decumanus Maximus* road, which contemporary overlay is illustrated in Figure 5, was reconstructed as a parallel road two centuries later during the absolute monarchy of Constantine the Great, when Thessaloniki became the second city of the Roman, and later Byzantine, Empire after Constantinople. This well-preserved marble-paved Byzantine avenue of the Justinian era was crossed by the other important pathway, *Cardo* that led to the harbor of the city (Makropoulou 2014).

A monumental gate of four pillars (*Tetrapylon*) that was placed at the intersection of these two roads was also discovered (Figure 4) and characterizes the road axis as *Via Colonata*, because it depicts the history of Thessaloniki during the 6th to 9th century AD. On the surface of the marble - paved road traces of horse-carriage use and engraved prints of exercising sports competitions were found (Makropoulou, 2014), thus indicating the city's center urban activity. The remains of public



buildings, a vast complex of fountains, retail stores and workshops alongside the Decumanus Maximus road (Figure 2) signify the urban development and constitute the monumental evidence of the social, commercial and administrative structure of Thessaloniki during the Early Byzantine era (Bouras *et al.* 2002). The extended excavations at the Venizelou Station have also revealed numerous of small items, jewelry, medals, silver and bronze bracelets that portray the practice of goldsmiths and silversmiths, which is still one of the main commercial activities in the area. It is noted that during 2012, the archaeologists discovered a small quantity of mercury at two Byzantine locations that depicts the already mentioned claim about this particular and intertemporal work practice for the commercial world of Thessaloniki. . Furthermore, the presence of numismatic evidence (i.e., European coins) indicates the continuous commercial transactions with other cities. In the course of the Ottoman period, the main road (*Decumanus Maximus*) became a pathway again and the Cardo road, that remained on the same direction to Venizelou street, was renamed to *Sambri Pasha* road from the name of *Vali Sabri Pasha* who ordered the widening of the road during the 1870s (Anastasiadis and Hekimoglou 1997). There were also many buildings that were discovered during the excavations at both sides of *Sambri Pasha*, which were built before and after 1917 along with the Muslim cemetery of *Alkazar yard*. During the approximately five centuries under the Ottoman rule the city became “multinational” (Mazower 2004) and there were three dominant nationalities (Jews, Ottomans, Greeks) which composed the majority of the population within the city walls. The Greeks were placed in the eastern part of the city along the length of the modern *Egnatia* Street. The center of the city was situated at the same position as it is located nowadays which portrays the historical continuity and the economic structures of the local society (Dimitriadis 1993). Under the period of the Ottoman rule, Thessaloniki regained the status of a major cosmopolitan city it had enjoyed during the early Christian era and at the end of the Ottoman Empire, it again became the administrative center of the region. In the case of Venizelou station, the revealed, well-preserved, archaeological ensemble “interacts” with the landmarks of the Ottoman era as *Hamza Bei Camii*, *Bedesten* and *Bei Hamami*, which were built during the 15th century and represent the city trade center (Memorandum of the Association of Greek Archaeologists, 8/10/2013). The modern period of the city is marked by the Great fire of 1917, which destroyed most of the buildings along Venizelou Street until the center was reconstructed according the urban plan of Ernst Hébrard.

Briefly, the picture that has been formed according the excavated area portrays the city’s urban continuity of approximately six centuries, from the 4th to the 9th century and constitutes unique archaeological scenery throughout different chronological periods. Apparently, the demonstration of the historical continuity requires a holistic approach to consider the Roman and Byzantine

antiquities along with the monuments of the Ottoman era that depict the religious and commercial activities. As a result, the construction of the Venizelou metro station in association with the exhibition of the archaeological findings as a vivid museum can be seen according the International Cultural Heritage Principles.

## APPROACH ADOPTED TOWARDS A SUSTAINABLE, MULTI-OBJECTIVE SOLUTION

An important turn point in the case of the Venizelou Station archaeological findings was the initial decision of the Central Archaeological Council (CAC) indicating removal, transfer, temporary storage and exhibition of the entity of the antiquities in a renovated barracks at the west side of the city. This decision was officially announced during an Attiko Metro press conference, as it was articulated on the respective press release of February 12th, 2013 (Attiko Metro 2013). Naturally, the above ambiguous decision triggered a major technical conflict and public debate at a governmental, scientific and social level.

Given the above deadlock, it was deemed necessary by the authors of this paper to first identify the phases to move forward:

- Constructively interact with all key decision- and public opinion-makers
- Form a set of performance (technical, historical, cultural, social, architectural and financial) criteria against which all possible alternative solutions could be comparatively assessed
- Work in technical detail on the most promising solutions
- Prioritize the alternative schemes, based on the quantitative and qualitative criteria defined in (b) to facilitate an optimized multi-objective decision-making

The successive steps are described in the following sections.

### **4.1 Interaction with key players and stake holders**

Due to the inherent technical nature of the initial dilemma regarding the feasibility of retaining the antiquities without canceling the operation of the station, the Civil Engineering Committee was inevitably the first group that had to interact with all involved parties. Along these lines, a series of in-situ visits were planned in collaboration with the the 9th Ephorate of Byzantine Antiquities, the Association of Greek Archeologists and the contractor Attiko Metro. Meetings also took place in the Ministry of Public Works in Athens along with the rector of Aristotle University, the president of the Attiko Metro and the director of the Thessaloniki Metro. At that point the solution of the temporary removal and the replacement of the antiquities was put forward for the first time by the Department of Civil Engineering.

## 4.2 Performance Objectives

This extensive exchange of ideas and effort to establish a common ground resulted into the definition of the foreseen performance criteria that any proposed solution should satisfy, particularly in relation to:

1. In-situ preservation of the archaeological findings. Even though the term “preservation” itself is indeed controversial and subjective, the interpretation made refers to the process of ensuring that value embodied in the cultural heritage is guaranteed of recognition and treated accordingly (Forrest 2010). This practically implied the sustainable restoration and enhancement respecting the multidimensional character of the monument and employing the contribution and cooperation of various experts.
2. Alignment with the principles of the main global heritage conventions (UNESCO Convention for the Protection of the World Cultural and Natural Heritage, Paris, 16 November 1972 / UNESCO Recommendation on International Principles Applicable to Archaeological Excavations, 5 December 1956 / UNESCO Declaration concerning the Intentional Destruction of Cultural Heritage, 17 October 2003), which require conservation and enhancement of the historical and aesthetic values of the monuments along with the preservation of authentic materials and structures (Forrest 2010).
3. Alignment with the Convention of Amsterdam (1975) so that the intergraded conservation is firmly based not only on the protection of the monument but also on the interacting function of the surroundings (in this case the nearby Roman, Byzantine and Ottoman cultural sites) so that the integrated conservation promotes the assimilation of the cultural heritage elements to the needs and uses of the contemporary social life and additionally the incorporation to the urban development (Pickard 2001).
4. Preservation and exhibition of the excavated antiquities as a cultural entity
5. Demonstration of the eternal character of the city, particularly in terms of its successive archaeological layers that have to be adequately displayed,
6. Promotion of the co-existence of the archaeological site with everyday life of the passenger – visitor in order to provide a kinaesthetic experience. Establishing an interactive relationship between the passengers and the antiquities, by driving the passenger’s flow within the preserved archaeological findings thus creating a living museum at the heart of Thessaloniki.
7. Satisfaction, if possible, of the preservation principles of the findings at their exact location, ideally without detachment.

8. Full functionality of the Venizelou Station, based on the data provided by the contractor that the cancellation of the station was essentially a “no-option” for mechanical reasons related to minimum required distance to attract the driverless trains from two successive stations. The particular criterion was further strengthened by the feedback from representatives of the commercial stores owners that were already heavily affected by the long term construction works in the area; thus a potential cancellation may lead them to closure.
9. Utilization of the diaphragm wall, which was already, constructed prior to the excavation and reveal of the archaeological findings, thus, setting the geometrical limits of the problem.
10. Suggestion of a technically feasible solution based on the existing expertise and resources.
11. Avoidance of extensive additional excavations or archaeological investigations outside of the perimeter of the station, as the latter could further increase the construction cost and potentially require contract amendments with the funding source thus jeopardizing the continuation of the project.
12. Avoidance of extensive delay in the construction of the Venizelou Station and the Metro line as a whole.
13. Avoidance of excessive additional construction cost, particularly given the financial crisis that burst in Greece since 2009.
14. Mitigation of potential natural hazards, such as earthquakes and floods.
15. Mitigation of man-made hazards, such as human vandalism.
16. Achievement of the highest safety and serviceability standards for the passengers while ensuring safety, security and maintenance of the antiquities.
17. Minimization of danger for the integrity of the findings due to possible relocation, detachment, transfer etc.

## 5. ALTERNATIVE TECHNICAL SOLUTIONS EXAMINED

### 5.1 Underpipping (Solution #1)

As the level of the archeological findings (at a depth of -6.0m) essentially coincided with the foreseen Level -1 of the station (Figure 6) it was deemed interesting to investigate the feasibility of “underpipping” Level -1 to the construction below the “sensitive” layer of the historical site. This approach was inspired by the construction model of the Central Artery/Tunnel Project (CA/T) of the Boston subway (else known as “Big Dig”), that rerouted the Central Artery (Interstate 93) which was the chief highway through the heart of Boston, into the 5.6 km Thomas P. O'Neill Jr.



Tunnel. The idea herein was to override the level of the archaeological findings through concrete injection under pressure. This technique in particular permits the strengthening of the ground and the formation of a supporting shell for every underground level, into which the electromechanical equipment could be installed (Figure 7).

This solution, though innovative and feasible in other cases, was considered of high cost. It is noted that the Big Dig was the most expensive highway project in the U.S. at the time and was plagued by escalating costs and scheduling overruns (Ngowi 2007). Furthermore, the necessity of lateral access was deemed prohibitive in the case of the densely populated area of the Venizelou station, needless to mention the requirement for the complete re-design of the station itself. Consequently, the underpinning approach was reckoned not suitable in practical terms.

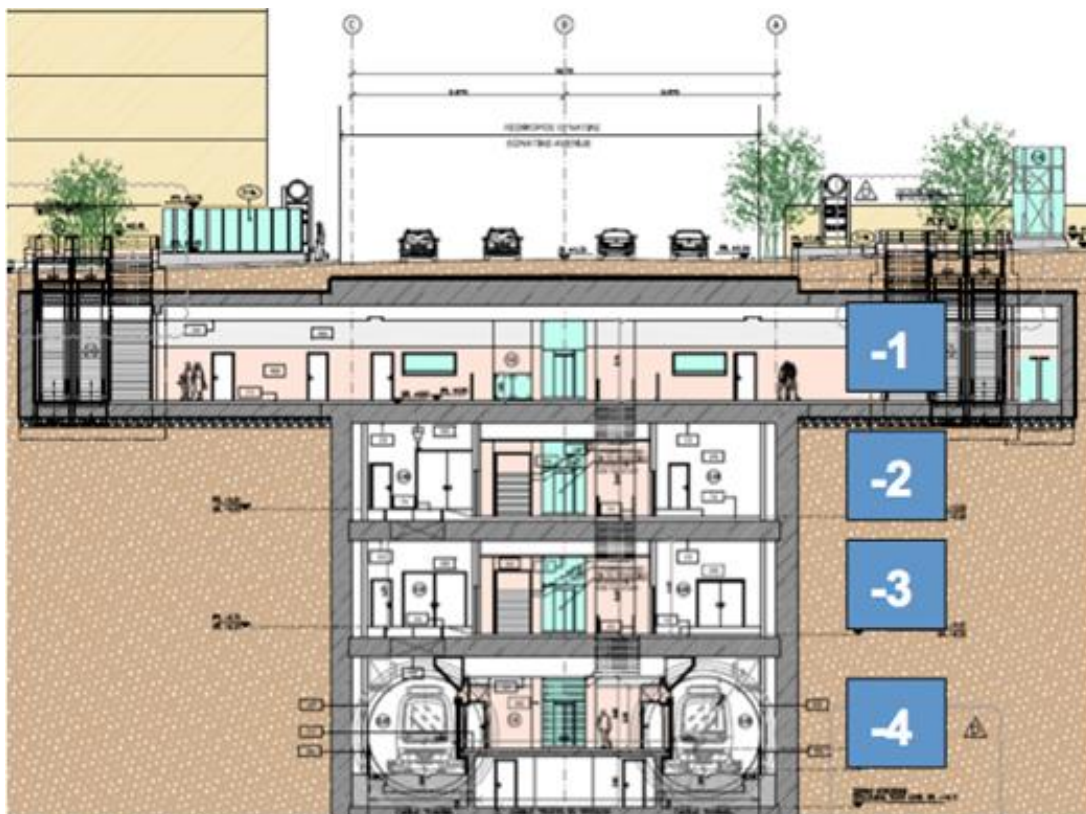


Figure 6: Cross Section of The Venizelou Station. Source: Attiko Metro

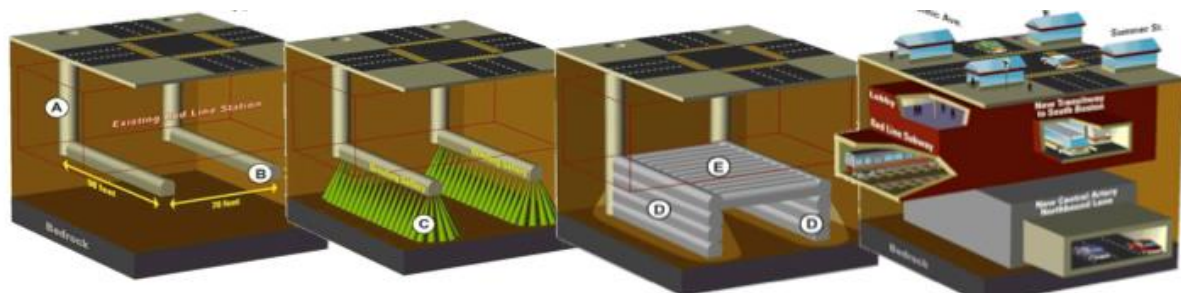


Figure 7: Example of station underpinning according to the novel solution of Boston Metro  
[Source: Illustrations available at Engineering.com]

## 5.2 Temporary detachment, storage and relocation of the antiquities

Aligned with the initial concept put forwards by the Department of Civil Engineering Committee, the solution that attracted more scientific attention was based on the following concept:

- temporary detachment of the entirety of the archaeological findings found at a depth using the GIS mapping, and removal technique used (at a smaller scale) in the preceding excavation of the Agia Sofia station,
- temporary relocation of the detached antiquities at another site,
- excavation according to the initial design down to the platform Level -4, at a depth of -23m,
- construction of the station up to the reference Level -1 at a depth of -6m and subsequently,
- replacement at the maximum possible extent of the antiquities at their original position based on their GIS trace.

The above main concept was investigated in two different alternative schemes of different degree of modification of the initial design:

### 5.2.1 *Repositioning of the entirety of the findings along with traffic divergence directly to Levels -2 and -3 (Solution #2)*

In an effort to ensure that the entirety of the antiquities will be replaced back to their original spot, the scenario of diverting the passenger flow directly down to Level -2 and -3 was first investigated. According to this approach, cancelation of the escalators should take place at Level -1. Specifically, the preserved antiquities at Level -1, which cover the vast majority of the excavated area and present great overlapping with the station foreseen facilities (Figure 8,) are maximized to 100%; furthermore the re-installation is required of the entirety of the electromechanical equipment of Level -1 to another level. However, bypassing the archaeological findings at Level -1, does not comply with the criterion set by the authors for continuous interaction of the passenger's with the archaeological site and the sense of a *living museum*. This is of course a quite subjective issue that is open for scientific discussion for which there is certainly not a unique approach. The criterion of human interaction with the city's past and the co-existence of public benefit with the heritage exhibition was considered by the authors certainly more important than the in-situ preservation of the entirety of the findings. The primary reason for this approach is based on the previous analogous experience from the case of the Athens Metro, where the maximum preservation concept, when diverged from the actual passenger's traffic, led to minimum visibility and number of visitors of (otherwise magnificent) archaeological spots. Furthermore, the notion of "entirety" of the archeological findings to be preserved is in way misleading, as the revealed "entire" parts of the Decumanus and Cardo Roads were essentially dictated by the cutting-off diaphragmatic walls,

the Roads themselves being by no means limited within the area of the excavation box. On the difficult dilemma between “entirety” and “visibility” the authors leaned more towards the latter one, i.e. the concept of the living museum.

### *5.2.2 Repositioning of the majority of the findings in a dual “operation through exhibition” concept (Solution #3)*

The particular concept stems from the basic assumption that the most important criterion is to deliberately drive the traffic through the priceless archeological antiquities to be exhibited as part of the station functionality. It practically involves the use of only one of the initially two escalators at Level -1, so that the passengers are led through the “archaeological” floor. This solution involves cancellation of a number of electromechanical equipment at Level -1 and their relocation to lower levels along with a number of management facilities and control rooms as shown in Figure 9. The passenger’s traffic is designed to flow over an ad-hoc designed high-strength glass floor (Figure 10) wherein carefully selected observation spots can be prescribed after appropriate architectural and archeological design studies (Figures 11,12,13).

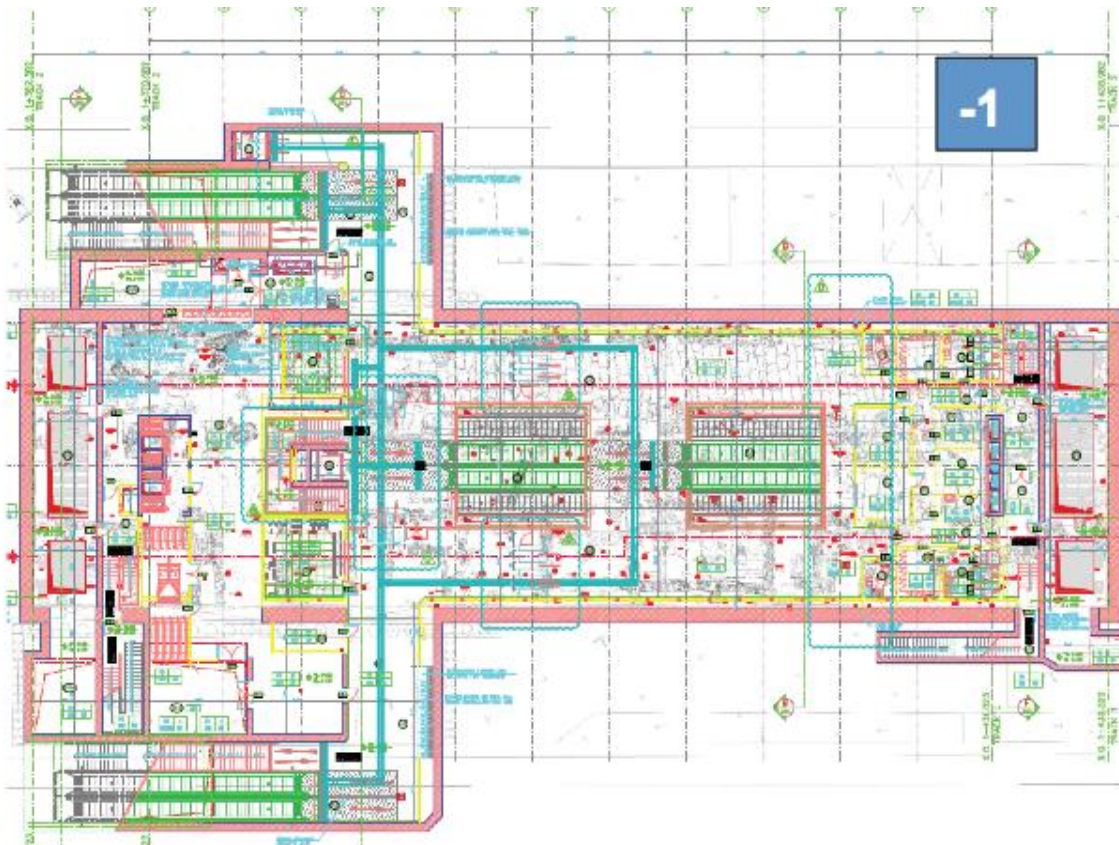


Figure 8: Overlapping between the initial design of the station and the archaeological findings, illustrated in grey color. Source: Attiko Metro



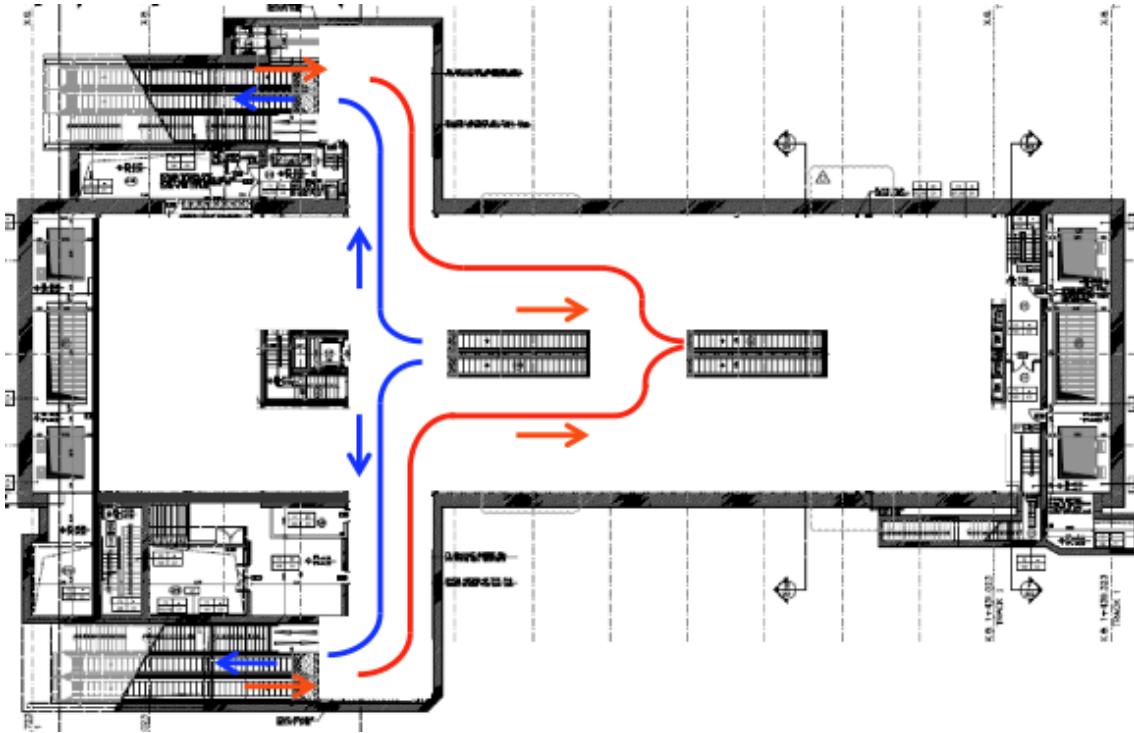


Figure 9: Passenger's flow according to the proposal of the Civil Engineering Committee after significantly reducing the (initially planned) Metro facilities at the "archeological floor", at Level -1.

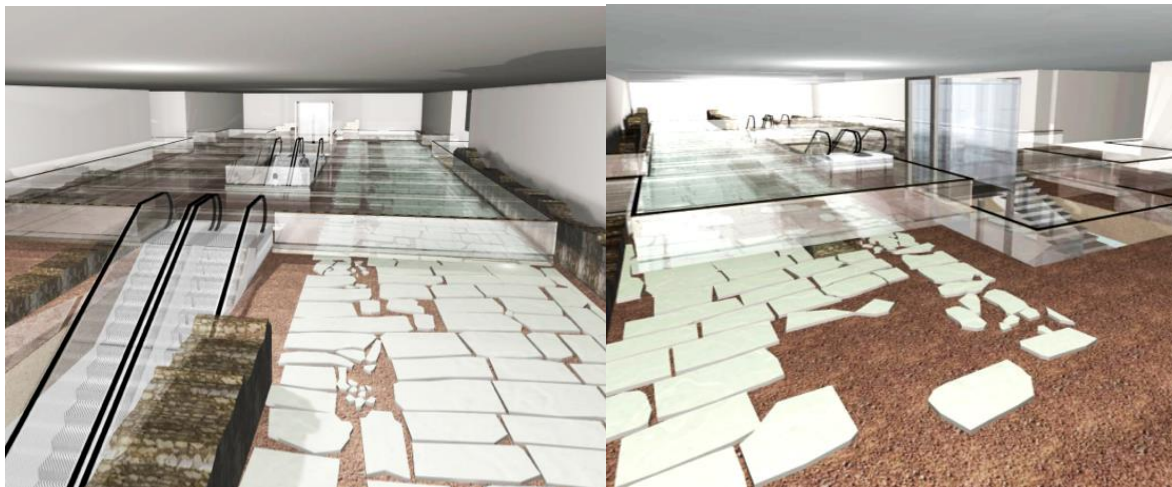


Figure 10: Rendered illustrations of passengers' interaction with the vast majority of the archaeological findings preserved site.





Figure 11: Rendered illustrations of passengers' interaction with the vast majority of the archaeological findings preserved and exhibited in-situ.

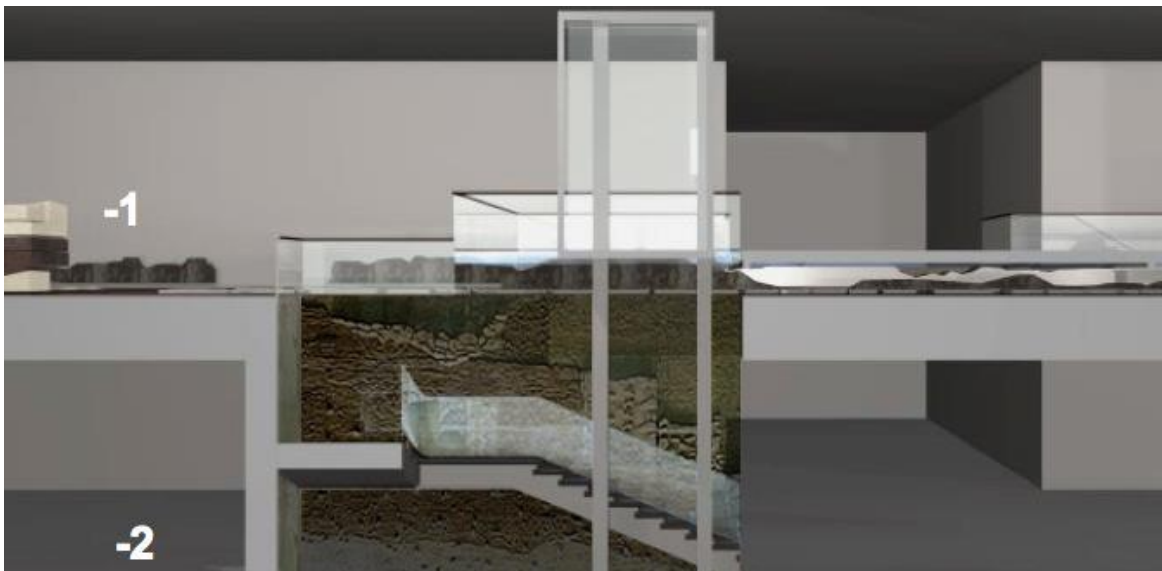


Figure 12: Cross-section at the location of the escalator publically demonstrating the different archeological layers of the city's past.

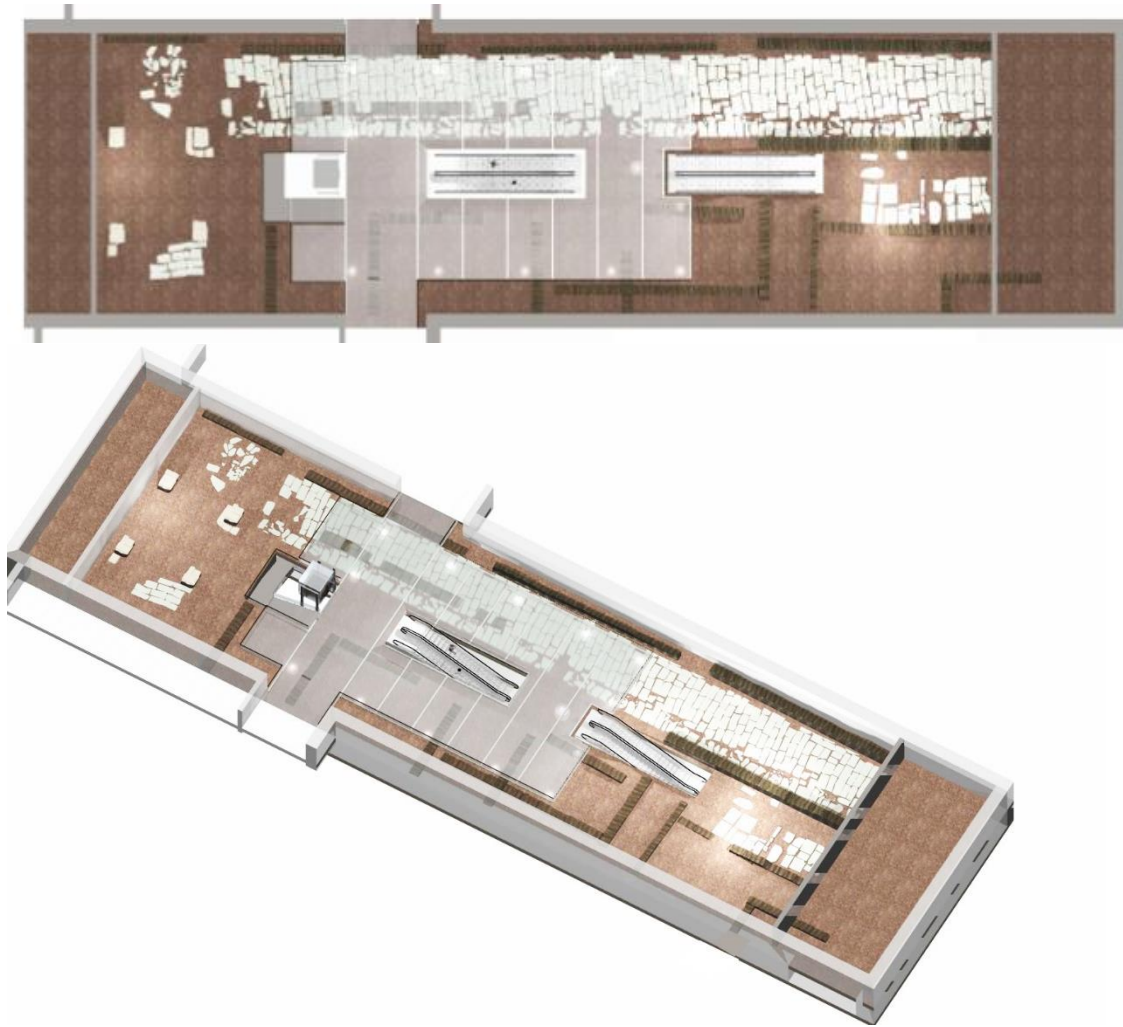


Figure 13: Top view of the glass floor over the preserved antiquities at level -1.

The benefit of such an approach, apart from the sense of interaction with the city history, is the limited required excavation around Level -1 to accommodate some facilities to be transferred, thus reducing the risk of an additional tender that could potentially affect the project schedule. Additionally, this proposal allows the protection of the ventilation manholes at their original location, thus avoiding the substantial additional cost of their relocation and limits the escalator's width only at the necessary space. Simultaneously, this approach alters the traffic flow by distinguishing between the downward and the upward passengers' wave in order to maintain safety and comfort high standards, while shifting the control rooms located at the east and west wing apart from Level -1, without any serviceability implications.

Detailed engineering calculations and drawings justified the feasibility of the proposed solution based on structural and geotechnical codes of design, as well health and safety regulation that are not presented herein in detail due to space limitations.

Table 1: Assessment of the proposed Solution #3 against multiple decision-making criteria

	<b>Archeological &amp; Museological &amp; Urban Planning Criteria (40%)</b>	<b>Justification</b>	<b>Score</b>
1	In-situ preservation of the archaeological findings	By 85% inclusive of 90% of the length of the Decumanus and Cardo paved roads, across their entire width, as well as the entire "Tetrapylon"	85%
2	Alignment with the principles of the main global heritage conventions	Partially, as 85% of the authentic materials are preserved. Limited lowering of the masonry around the escalator.	70%
3	Integration within the wider neighborhood and its cultural identity	Feasible after appropriate study	80%
4	Exhibition of the excavated antiquities as a cultural entity	At a great degree	75%
5	Demonstration of the eternal character of the city (exposure of different eras vertically)	Through soil layer cross sections around the glass walls of the escalator	90%
6	Experience the antiquities daily as a "living museum"	Yes	100%
7	Violation of "in-situ" principles due to possible detachment even if antiquities are re-deployed	Even though relevant research is not conclusive on this criterion, inevitably, it is not satisfied	30%
	<b>Technical Criteria (25%)</b>	<b>Justification</b>	<b>Score</b>
8	Full functionality of the station	Yes	100%
9	Utilization of the diaphragm wall	Yes	100%
10	Technical feasibility (structural, geotechnical & E/M) retaining safety and serviceability standards	Yes, with limited additional designs	100%
	<b>Project Management &amp; Feasibility Criteria (25%)</b>	<b>Justification</b>	<b>Score</b>
11	Avoidance of extensive additional (out of the diaphragm) archaeological investigations	Yes	100%
12	Avoidance of extensive construction delay	Delay estimated to approximately 9 months. It is noted that station and project progress are parallel, hence, the local and project delay are essentially uncorrelated.	80%
13	Acceptable additional construction cost (inclusive of potential detachment and storage)	Additional cost (including the cost of detachment, relocation and temporary storage) is estimated to 2.8-3.0M€, corresponding to 0.3% of the total project construction cost.	80%
	<b>Safety, Security &amp; Maintenance (10%)</b>	<b>Justification</b>	<b>Score</b>
14	Exposure to natural hazards (earthquake, flood)	Antiquities are generally squat and robust hence seismic vulnerability limited.	70%
15	Exposure to man-made hazards (vandalism)	Existing, however, similar to other historical sites.	60%
16	Ease and cost of maintenance	Maintenance cost not excessive since antiquities are generally protected from weathering, rain and other climatic effects.	60%
17	Danger from possible detachment & storage	Needs advanced techniques but this has already been accomplished successfully in the nearby Ag. Sofia Station	60%

The above compromise of temporary detachment and partial replacement leads to a preservation of approximately 85-90% of the area of the archeological findings inclusive of 90% of the length of the Decumanus and Cardo paved roads, across their entire width as well as the entire “Tetrapylon” (four pillars) crossroad gate along with the six constituting pillars. The eternal character of the city is also impressively demonstrated by the use of glass walls around the main escalator, although a minor shearing off (i.e., height reduction) of approximately 5-8% of the findings will be required next to the main escalator to lower the masonry at the level of the glass designed to serve passenger’s access.

## 6. COMPARATIVE ASSESSMENT OF ALTERNATIVE PROPOSALS AGAINST MULTIPLE, QUANTITATIVE AND QUALITATIVE, CRITERIA

### 6.1 Standalone assessment of Solution #3 towards multiple-criteria

The evaluation of the projected solution was based on the 16 archaeological, museological, urban planning, technical, project management, safety and maintenance criteria presented in section 4.2. Table 1 summarizes how the particular solution meets the performance criteria set. A relevant score is also assigned per criterion. This assessment is further used as the basis for the comparative evaluation of the different solutions, as presented in the following.

### 6.2 Comparative evaluation of solutions examined

#### 6.2.1 MCA Methodology

Four are the alternative solutions that are evaluated as listed below:

- Solution #0: The initial decision of removing the antiquities, storing them off-site and exhibiting them in a museum at the west side of the city.
- Solution #1: Underpipping, as discussed in Section 5.1.
- Solution #2: Repositioning of the entirety of the findings along with traffic divergence directly to Levels -2 and -3 as discussed in Section 5.2.1.
- Solution #3: Repositioning of the majority of the findings in a dual “operation through exhibition” concept as discussed in Section 5.2.2.

Given that the problem studied cannot be expressed solely in monetised and measurable terms, the conventional Cost-Benefit Analysis (CBA) is not adopted. Indeed, CBA is very efficient and straightforward in assessing quantitative effects or exposing hidden costs, however, it is not appropriate for evaluating “soft” or non-monetised criteria, such as those associated with cultural heritage (Beria *et al.* 2012). Along these lines, a Multi-Criterion Assessment (MCA) methodology is employed (Spackman 2013) for comparatively assessing the above solutions examined. Due to the



combination of both quantitative and qualitative criteria, it is necessary to either standardize the scores across all criteria using the Expected Value method, or to normalise the importance of each criterion and use assessment scores varying within a standard and common range. A number of other weighting methods can be also found in the literature, primarily distinguished as compensatory and non-compensatory (Grafakos *et al.* 2010). A standard relative weighting technique (Communities and Local Government UK 2009) was adopted herein, as it represents a common approach in governmental decision-making (HM Treasury 2011). The successive steps of this methodology, as implemented in the particular case of the Venizelou Station antiquities, are discussed below:

- Step 1: The 17 performance objectives set in Section 4.2 were translated into relevant criteria and were then grouped in four major categories of different category weights (CW) for decision-making: (a) Archaeological & Museological & Urban Planning Criteria (with an overall weight  $CW_1=40\%$ ), (b) Technical Criteria (weight of  $CW_2=25\%$ ), (c) Project Management & Feasibility Criteria (weight of  $CW_3=25\%$ ), and (d) Safety, Security & Maintenance (with a weight of  $CW_4=10\%$ ). Apparently,  $\sum_{j=1}^{m=4} CW_j = 1$ .
- Step 2: For each criterion, an Impact Index (R) was assigned in the scale 1-10 (1 corresponding to negligible and 10 to maximum impact). These Impact Indices were assigned based on stakeholder's opinions, expert knowledge and the authors engineering judgment, all resulting from the extensive interactions of the authors with Attiko Metro, as well as with governmental, municipal, and archaeological authorities.
- Step 3: Based on the above index R, the obtained scores were translated into normalized relative importance factors (weights). The *relative weighting factor*  $wf_i$  was therefore derived within each one of the four criterion categories as:  $wf_i = R_i / \sum_{i=1}^n R_i$ , where N is the number of criteria in the respective categories (in our case  $n=7$  for Archaeological & Museological & Urban Planning Criteria,  $n=3$  for technical criteria,  $n=3$  for project management and  $n=4$  for safety and maintenance criteria).
- Step 4: Given the Impact Index (R) of each category, the *total weighting factor*  $wft_i$  was calculated for each one of the 17 criteria as:  $wft_i = wf_i \cdot CW_j$ . Similarly,  $\sum_{i=1}^{17} wft_i = 1$
- Step 5: Having defined the absolute weighting factor of each criterion, a Performance Matrix  $S_{i,k}$  was formed, with terms in the range 0-100, for all  $i=17$  criteria and the  $k=4$

solutions examined; where 0 denotes complete violation and 100 absolute satisfaction of the respective criterion.

- Step 6: The overall value of each solution  $k$  was then expressed as the total normalised score  $TS_k$ , computed as the weighted sum of the total weighting factor  $wft_i$  of each criterion and the corresponding score term:

$$TS_k = \sum_{i=1}^{17} S_{i,k} \cdot wft_i$$

The assumption is made that all criteria are mutually preference independent, which means the preference score of each option does not depend on the preference of the other.

### 6.2.2 Comparative assessment,

The application of the above methodology is presented in Table 2 where all values of  $CW$ ,  $R$ ,  $wft_i$ ,  $wft_i$  and  $TS_k$  are summarized. A first observation is that based on the resulting *total weighting factor*  $wft_i$ , the most influential criteria are preservation of antiquities onsite ( $wft_1=11.1\%$ ), technical feasibility ( $wft_{10}=10.9\%$ ), construction delay ( $wft_{12}=10.5\%$ ) and additional construction cost ( $wft_{13}=10.5\%$ ). It is noted, that even though the  $CW$  and  $R$  values have resulted from extensive interaction with experts, stakeholders and community representatives, the respective factors have an inevitable degree of subjectivity that propagates into the successive assessment steps. The same applies to the terms of the Performance Matrix  $S_{ik}$  which reflect the authors opinion. Given the above limitations, it is seen in Table 2 that Solution #0 (i.e., removing the antiquities, storing them off-site and exhibiting elsewhere), with an overall value of  $TS_1=58\%$  is rejected as it completely fails to address archeological Archaeological, Museological and Urban Planning Criteria (partial score is only 3%). The same applies to Solution #2 (under-pipping), which has a similar overall value of  $TS_2=57\%$  but is costly and technically very challenging, almost prohibitive in the particular dense environment (partial feasibility score is only 18%). Solution #3 (i.e., Bypassing the antiquities' level and preserving an "archeological level" at -1), with a total score of 74%, is superior to the first two as it satisfies to a great extent all archeological (84%), technical (91%) and safety criteria (82%) with the exception perhaps of feasibility and cost criteria (46%) which need to be carefully justified. It is noted that a version of the particular solution has been under further examination by the contractor and the central administration, through a different decision-making process. Solution #4 is deemed preferable by the authors as, at least according to their own methodology, weighting and scoring, it presents the highest overall value (84%), and a more balanced individual value in the four distinct categories, namely 80%, 100%, 83% and 57%

respectively. Most importantly, it preserves the majority of the antiquities offering a living archeological museum right in the heart of the passengers traffic, without introducing significant delays or costs in the construction of the station. Apparently, this challenging topic is open to further research.

## 7. CONCLUDING REMARKS

This paper provides an overview of the methodological steps undertaken to investigate the feasibility of preserving the archeological discoveries of unique value that were found during the excavation of the Venizelou Metro Station in the city of Thessaloniki, Greece, without jeopardizing the completion of the major technical project. It also demonstrates the qualitative and quantitative, archaeological, technical and project management criteria developed for assessing the alternative solutions investigated towards a “living museum” concept. It is deemed that the methodological multiple-criteria approach, which is presented herein, consists of a wider strategy for complex problem solving at a municipality level, that was proven successful in practice, particularly if viewed through the perspective of the specific timing. In fact, the strategy adopted by the authors of this paper constituted a crucial intervention at a turning point where all negotiations seemed infertile and the scientific and sociopolitical deadlock could easily lead to either moving the antiquities permanently or blocking the overall Metro project as a whole. Most importantly, it consists a unique example of integrating quantitative and qualitative criteria through a MCA analysis that lead to a balanced proposal simultaneously addressing a series of archeological, technical, feasibility, safety and maintenance criteria. Currently, after two years of challenging interactions between the key players, stakeholders and decision-makers, a matured situation has been developing in light of solutions #2 and #3 described herein, to satisfy the above objectives and exhibit the unique archaeological findings in-situ; an objective that is now unanimously accepted by all involved parties.

Table 2: Multi-Criterion Analysis of the alternative solutions for decision-making

					Solution #0	Solution #1	Solution #2	Solution #3
					Removing & exhibiting elsewhere	Underpipping & Exhibiting in Situ	Bypassing & Exhibiting in Situ	Replacing & Exhibiting in Situ
<b>Archeological &amp; Museological &amp; Urban Planning Criteria (40%)</b>	<b>CW</b>	<b>Imp. Index R</b>	<b>wf<sub>i</sub></b>	<b>wf<sub>i</sub></b>				
1 In-situ preservation of the archaeological findings	40%	10	27.8%	<b>11.1%</b>	0	100	100	85
2 Alignment with the principles of the main global heritage conventions		5	13.9%	5.6%	0	90	90	70
3 Alignment with the conv. of Amsterdam (integration with wider cultural identity)		2	5.6%	2.2%	0	80	80	80
4 Exhibition of the excavated antiquities as a cultural entity		5	13.9%	5.6%	10	100	100	75
5 Demonstration of the eternal character of the city (exposure of different eras vertically)		4	11.1%	4.4%	10	70	70	90
6 Experience the antiquities daily as a "living museum"		7	19.4%	7.8%	0	50	50	100
7 Violation of "in-situ" principles due to possible detachment & storage		3	8.3%	3.3%	0	100	100	30
		36			3%	84%	84%	80%
<b>Technical Criteria (25%)</b>	<b>CW</b>	<b>Imp. Index R</b>	<b>wf<sub>i</sub></b>	<b>wf<sub>i</sub></b>				
8 Full functionality of the Venizelou station	25%	8	34.8%	8.7%	100	100	100	100
9 Utilization of the diaphragm wall		5	21.7%	5.4%	100	40	100	100
10 Technical feasibility (structural, geotechnical & E/M) retaining safety and serviceability		10	43.5%	<b>10.9%</b>	100	20	80	100
		23			100%	52%	91%	100%
<b>Project Management &amp; Feasibility Criteria (25%)</b>	<b>CW</b>	<b>Imp. Index R</b>	<b>wf<sub>i</sub></b>	<b>wf<sub>i</sub></b>				
11 Avoidance of extensive additional (out of the diaphragm) archaeological investigations	25%	3	15.8%	3.9%	100	50	50	100
12 Avoidance of extensive construction delay		8	42.1%	<b>10.5%</b>	100	10	40	80
13 Acceptable additional construction cost (inclusive of potential detachment and storage)		8	42.1%	<b>10.5%</b>	100	15	50	80
		19			100%	18%	46%	83%
<b>Safety, Security &amp; Maintenance (10%)</b>	<b>CW</b>	<b>Imp. Index R</b>	<b>wf<sub>i</sub></b>	<b>wf<sub>i</sub></b>				
14 Exposure to natural hazards (earthquake, flood)	10%	4	14.8%	1.5%	100	80	80	70
15 Exposure to man-made hazards (vandalism)		9	33.3%	3.3%	100	90	90	60
16 Ease and cost of maintenance		6	22.2%	2.2%	90	80	80	60
17 Danger from possible detachment		8	29.6%	3.0%	40	100	100	60
		27			77%	82%	82%	57%
					<b>Σwf<sub>i</sub>= 100%</b>			
					<b>TS<sub>t</sub>=</b>			
					58%	57%	74%	82%

## ACKNOWLEDGEMENTS

The authors would like to thank Attiko Metro, S.A. and Thessaloniki Metro, S.A. as well as the CEO of the latter, Dr. G. Constantinides for making all the required data and drawing available. They also like to thank Mrs D. Tsirigoti for generating the 3D rendering the envisaged solution.

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